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GORBY GAMES - A GAME THEORETIC ANALYSIS OF DISARMAMENT CAMPAIGNS AND THE DEFENSE EFFICIENCY-HYPOTHESIS

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by Werner Güth
and Eric van Damme

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Gorby–Games*

– A Game Theoretic Analysis of Disarmament Campaigns

and the Defense Efficiency–Hypothesis –

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1989

* It is a pleasure to thank Rudolf Avenhaus for helpful comments.

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Abstract

A simple game model is described which tries to capture the strategic aspects of disarmament campaigns by Soviet Union's political leader Gorbachev. It is assumed that NATO is only incompletely informed about the true intentions of such campaigns which are expressed by two different types. Due to the hypothesis of efficient defense the Soviet Union can signal its intentions. As typical for signaling games there exists a vast multiplicity of equilibria, pooling and signaling ones. Equilibrium selection theory is applied to single out a unique solution which is always type signaling whenever such an equilibrium exists at all.

I. Introduction

In the following we want to describe and analyse a sequential game model which, in a stylized way, tries to capture the essential aspects of the strategic situations caused by Soviet Union's political leader Mihail Gorbachev. The model assumes that the North Atlantic Treaty Organization (NATO), which, for the sake of simplicity, is modelled as one player, has no imperialistic goals, but is only interested in effective defense. Regarding the Soviet Union it is not clear whether its motivation is mainly effective defense or expanding its area of influence. Correspondingly, we will distinguish two types of Soviet Union, namely a peaceful (p) and an imperialistic (i) type, see AVENHAUS, GÜTH, and HUBER, 1989, for a similar type distinction.

The other essential ingredients of our model are the DEH–hypothesis of efficient defense (see JERVIS, 1973, HUBER and HOFMANN, 1984, HUBER, 1987, and AVENHAUS et al., 1989), and the signaling character of the game. The defense efficiency hypothesis is needed to justify that a certain disarmament of offensive weapon systems is more costly for the imperialistic type i of Soviet Union than for the defense oriented peaceful type p. The signaling character results since Soviet Union is moving first so that the other player, by observing Soviet Union's first move, can infer which type is actually present.

According to the DEH–Hypothesis of efficient defense one can efficiently satisfy security needs by restructuring armed forces from offensive to defensive ones. Such a drastic restructuring will seriously limit the possibilities to attack foreign countries without endangering one's own security. Our interpretation of types implicitly assumes that disarmament proposals mainly concern military forces needed for offensive operations and that disarmament will induce a restructuring of armed forces from offensive to defensive ones.

Disarmament proposals for defense oriented weapon systems could be turned down both by an imperialistic and by a defense oriented type of country. By such proposals a country might want to signal security needs in the sense that it would welcome a balanced reduction of defensive forces. Here we do not want to consider such a situation but rely on disarmament proposals concerning weapon systems for offensive military operations. So what a country can signal is whether it wants to preserve its capability for major offensive operations or whether it is willing to sacrifice its own possibilities to attack foreign countries by restructuring armed forces from offensive to defensive ones.

A game theoretic analysis of such a move can give us some hints under which conditions disarmament proposals concerning offensive weapons will signal a purely defense oriented military policy. As typical for signaling games a definite answer will require more refined game theoretic solution concepts since there the model has many equilibrium points. Whereas the so–called pooling equilibria deny that disarmament proposals signal peaceful intentions, the so–called separating equilibria prescribe different choices for the imperialistic and the peaceful type of the Soviet Union. From a political point of view one may consider the multiplicity of equilibria as an advantage since they allow us to justify a broad spectrum of political views. But for game theory these games are certainly a challenge to develop concepts which provide more definite answers. It will turn out that this requires strict restrictions for belief formation.

The main shortcoming of our model, except for its rather stylized form, is the fact that NATO is modelled as a unique player. By this we necessarily have to exclude all intentions to destabilize NATO by disarmament proposals which are naturally welcomed by some NATO–member countries, e.g. the European NATO–members and rather unattractive to others, for instance, for the United States of America (USA). Here we have neglected such aspects since they seem to be less related to the defense efficiency hypothesis. A more complete analysis of Gorbachev's disarmament campaigns will, of course, have to take into account that these campaigns might cause serious conflicts between different NATO–member countries and thereby endanger NATO's political influence.

II. The game model

Since the NATO–player N is only *incompletely informed* about whether the Soviet Union G is of type G_i or G_p, the game starts with an initial fictitious chance move reflecting N's information deficit about G's true type. The probability for the peaceful type G_p of G is w with $0 < w < 1$, whereas the imperialistic type G_i of G is expected with the complementary probability 1–w. The probability parameter w reflects N's prior beliefs concerning the true type of G where N's prior beliefs are assumed to be common knowledge.

Knowing its type $t \in \{i, p\}$ the selected type G_t of G can then choose its disarmament proposal d_t with

$$0 \leq d_t \leq D$$

where D (> 0) is the greatest arms reduction level which even a peaceful country will not want to exceed. The meaning of d_t is that the Soviet Union is willing to accept any disarmament agreement which will not abolish more weapons than d_t. Thus G's disarmament proposal d can be seen as offering a whole range of disarmament agreements. If this range is large and the agreed upon disarmament relatively small, the NATO–player N is responsible for staying below the initial proposal.

The NATO–player N oberves the proposal $d \in [0,D]$ but does not know the type G_t of G which has made the proposal. Knowing d, player N can choose any disarmament level l in the range

$$0 \leq l \leq d.$$

After player N's move l the game ends (in case of $d_t = 0$ it actually ends already before since N has no decision to take).

Define

$$\delta = \begin{cases} 0 & \text{if } l = 0 \\ 1 & \text{if } l > 0; \end{cases}$$

in case of $\delta = 1$ we speak of a disarmament agreement; in case of $\delta = 0$ no arms reduction has been arranged. The payoff of N is determined by

$$U_N = \begin{cases} l & \text{if } t = p \\ -cl & \text{if } t = i \end{cases}$$

where c (> 0) measures the security loss of a disarmament agreement with the imperialistic type of G. If the payoff function for t = p is linear one can write it in the form given above by appropriately choosing the unit of measuring disarmament. Thus the main assumptions underlying the definition of U_N are the linearity of U_N in l and the natural condition that disarmament contracts with G_p are desirable and those with G_i are not.

The payoff function U_t for the types $t \in \{i, p\}$ of G are given by

$$U_t = \delta - c_t l \text{ with } c_p \leq 0 < c_i^{-1} \leq D .$$

Here $\delta = 1$ is the positive publicity effect of having initiated a disarmament campaign which has reduced armament on both sides. The second term $c_t l$ is the security loss implied by an arms reduction in the order of l. The essential assumptions are again the linearity in the disarmament level l as well as the intuitive condition that, due to the efficiency hypothesis for defense, only the peaceful type does not suffer from disarmament. Condition $c_i^{-1} \leq D$ is imposed in order to allow that the peaceful type G_p of G can signal its peaceful intentions. In case of $c_i^{-1} > D$ one would have $1 - c_i d > 0$ for all d, i.e. the imperialistic type will always mimic the peaceful one. This case will be discussed in Section V below.

For the two types t of G a strategy is simply the choice of a disarmament proposal d_t with $0 \leq d_t \leq D$. A strategy of N is a function

$$\begin{aligned} l(\cdot) : [0,D] &\longrightarrow [0,D] \\ d &\longmapsto l(d) \end{aligned}$$

which assigns a disarmament level $l(d)$ with $0 \leq l(d) \leq d$ to every proposal $d \in [0,D]$.

III. Multiplicity of equilibria

In the following we want to illustrate the multiplicity of equilibria for the game Γ described in Section II which is a typical phenomenon in signaling games (see, for instance, GÜTH and VAN DAMME, 1989). In a signaling game there are players who are informed about certain aspects of the rules of the games whereas other players have only prior probabilistic beliefs concerning these aspects. Furthermore, the informed players have to decide before the uninformed players who, therefore, might deduce from the actions of the informed players what the informed players know. Since the Soviet Union player G (respectively, its political leader Gorbachev) is assumed to decide before the NATO–player N is going to move, G might reveal his type by his opening move d. Thus Gorby's NATO–game allows the Soviet Union to signal by its proposal whether its intentions are peaceful or imperialistic.

A strategy vector $s^* = (s_1^*,...,s_n^*)$ of an n–person game with strategy sets S_j for $j = 1,..,n$ is an <u>equilibrium point</u> if for $j = 1,...,n$ player j's strategy is a best reply to s^*, i.e. if

$$U_j(s^*) \geq U_j(s_1^*,...,s_{j-1}^*,s_j,s_{j+1}^*,...,s_n^*)$$

for all strategies s_j of player j. $U_j(s)$ is the payoff of player j for the play implied by the strategy vector s.

For the example at hand one has n = 3 and

$$S_t = [0,D] \text{ for } t \in \{i, p\}$$

whereas S_N is the set of all functions

$$\begin{aligned} l(\cdot) : [0,D] &\longrightarrow [0,D] \\ d &\longmapsto l(d) \text{ with } 0 \leq l(d) \leq d. \end{aligned}$$

A pure strategy vector is denoted by $s = (d_i,d_p,l(\cdot))$, i.e. by listing the opening moves d_t of the two possible types t of G as well as player N's decision function $l(\cdot)$ describing how he is going to react to all possible proposals d by player G.

The first class of equilibria $s^* = (d_i^*,d_p^*,l^*(\cdot))$, which we consider, are the so–called *pooling or non–type revealing* equilibria according to which one has

$$d_i^* = d_p^* = d,$$

i.e. both types $t \in \{i, p\}$ of player G propose the same disarmament level d so that d does not reveal the type of G. To support such a behavior the decision function $l^*(\cdot)$ can be defined as

$$l^*(\hat{d}) = \begin{cases} \hat{d} & \text{if } \hat{d} = d \\ 0 & \text{if } \hat{d} \neq d. \end{cases}$$

The strategy vector $s^* = (d,d,l^*(\cdot))$ is an equilibrium point if for $d > 0$ the following conditions are satisfied:

$$1 - c_i d > 0 \text{ or } d < c_i^{-1}$$

and

$$w-(1-w)c > 0 \text{ or } c < \frac{w}{1-w}.$$

The first condition makes sure that type G_i of G does not want to make a proposal d_i whose acceptance is unprofitable for him. The second condition guarantees that it is optimal for player N to accept the proposal d.

Of course, the choice behavior $l^*(\hat{d})$ for $\hat{d} \neq d$ is intuitively rather unreasonable since disarmament proposals d with $d > c_i^{-1}$ are to be expected only by G_p and should therefore be accepted. But this is not ruled out since in equilibrium player N never encounters disarmament proposals $\hat{d}$ with $\hat{d} \neq d$. All proposals $\hat{d} \neq d$ are 0–probability events so that player N is free to form arbitrary beliefs since *Bayes–rule* (BAYES, 1763) cannot be used to assign conditional probabilities for facing G_i and G_p, respectively. This arbitraryness of beliefs is somewhat reflected by the way in which N reacts to proposals $\hat{d} \neq d$. If we, for instance, assume $l(\hat{d}) = 0$ for all $\hat{d} \neq d$, this indicates that N, after observing $\hat{d}$, expects G_i with very high probability. If N believes that $\hat{d}$ ($\neq$ d) will not be used by both types of G, his strategic expectations have no implications at all for his posterior beliefs since they exclude the choice of $\hat{d}$. In other words: N is not all restricted in his posterior beliefs by his strategic expectations.

Proposition 1: For $c < \frac{w}{1-w}$ all disarmament proposals $d_i^* = d_p^* = d$ with $0 < d < c_i^{-1}$ and decision functions $l^*(\cdot)$ with

$$l^*(\hat{d}) = \begin{cases} \hat{d} & \text{if } \hat{d} = d \\ 0 & \text{if } \hat{d} \neq d \end{cases}$$

define pooling equilibria of Gorby's NATO–game Γ. □

Note that Proposition 1 describes not all pooling equilibria since also $d = 0$ can be an outcome of a pooling equilibrium. According to Proposition 1 there exists a vast multiplicity of pooling equilibria which all imply a non–revealing opening move by player G. Of course, $s = (0,0,l(\cdot) \equiv 0)$ is also an equilibrium point but one in dominated strategies since for G_p it is never worse and sometimes better to use $d_p > 0$ instead of $d_p = 0$. Similarly, $s = (c_i^{-1}, c_i^{-1}, \hat{l}(\cdot))$ with

$$\hat{l}(\hat{d}) = \begin{cases} \hat{d} & \text{if } \hat{d} = c_i^{-1} \\ 0 & \text{if } \hat{d} \neq c_i^{-1} \end{cases}$$

is an equilibrium point in dominated strategies since any proposal d_i with $d_i < c_i^{-1}$ is never worse and sometimes better than $d_i \geq c_i^{-1}$.

Type revealing or separating equilibria are given by $s^* = (d_i^*, d_p^*, l^*(\cdot))$ with $d_i^* < c_i^{-1}$, $d_p^* \geq c_i^{-1}$, and

$$l^*(d) = \begin{cases} d & \text{for } d = d_p^* \\ 0 & \text{otherwise}. \end{cases}$$

Obviously, no player can gain by unilaterally deviating from s^*. For G_i it does not pay to mimic G_p since $1 - c_i d_p^* \leq 0$ due to $d_p^* \geq c_i^{-1}$. For the others there is simply no better choice given the behavior of all other players as described by s^*.

Proposition 2: All strategy vectors $s^* = (d_i^*, d_p^*, l^*(\cdot))$ with $d_i^* < c_i^{-1}$, $d_p^* \geq c_i^{-1}$, and

$$l^*(d) = \begin{cases} d & \text{for } d = d_p^* \\ 0 & \text{otherwise} \end{cases}$$

are type separating equilibria of Gorby's NATO–game Γ. □

It should be mentioned that Proposition 2 does not describe all type separating equilibria. Since G's proposal is rejected anyhow, d_i^* could be chosen also in the range $d_i^* \geq c_i^{-1}$ although such strategies are dominated. According to Propositions 1 and 2 the equilibrium concept alone is not sufficient to rule out unreasonable beliefs of player N and thereby equilibria relying on them. Nearly nothing can be said about the solution by just requiring the equilibrium property. In the following we will therefore apply equilibrium selection theory (see HARSANYI and SELTEN, 1988, as well as GÜTH and KALKOFEN, 1989) in order to derive unambiguous predictions about the rational decision behavior in Gorby's NATO–game Γ.

In our view, political reactions to the disarmament campaigns, initiated by Soviet Union's political leader Mihail Gorbachev, reflect the two kinds of equilibrium points. Anti–communistic hardliners often argue that up to the most recent past all the changes in the Soviet Union are just a matter of publicity, political illusions or interpretations and that it has not yet been proved that the Soviet Union has given up its imperialistic intentions. They are obviously justified in asking: What proves that a still imperialistic Soviet Union is not trying to mimic a truly peace loving one in order to strengthen the political influence of groups and parties in NATO–member countries which want to reduce NATO's military forces or are even arguing that NATO in its present form has become obsolete?

On the other hand many reactions, even by leading politicians clearly reveal the signaling equilibrium interpretation of Gorbachev's disarmament campaigns. According to this point of view, no truly imperalistic country could be interested in such drastic balanced reductions of military forces. So these proposals undoubtedly reveal that at least now the Soviet Union has no desire to expand its area of influence by military means.

Our results show that both these viewpoints are supported by appropriate equilibrium outcomes. Thus by relying on the equilibrium concept alone nothing much can be said whether one point of view is more justified than the other. In the following we therefore explore whether more refined game theoretic solution concepts can help us to decide whether the signaling interpretation of Gorbachev's disarmament is more reasonable than the pooling interpretation of anti–communistic hardliners and which specific equilibrium of the chosen type is selected as the solution.

IV. Equilibrium selection

The main step in restricting the multiplicity of equilibria in signaling games is to avoid the arbitrary formation of beliefs in unreached information sets. Equilibrium selection theory (see the pioneering approach by HARSANYI and SELTEN, 1988) avoids this by analysing the ϵ–uniformly perturbed games Γ_ϵ of Gorby's NATO–game Γ. Assume first of all that there exists a smallest positive unit g for measuring military strength (e.g. one tank, or one missile etc.) and that all disarmament proposals and agreements have to be integer multiples of g. In an ϵ–uniformly perturbed game Γ_ϵ all proposals d_t and all possible acceptance decisions

$l(d)$ for any given d have to be chosen with the positive minimum probability ϵ which has to be sufficiently small such that players still have some freedom to choose their moves. Thus in an ϵ–uniformly perturbed game Γ_ϵ all information sets are reached with positive probability so that Bayes–rule can always be applied to derive posterior beliefs.

Assume that one can solve uniquely all ϵ–uniformly perturbed games Γ_ϵ of Gorby's NATO–game Γ. The solution for Γ is then simply the limit of the solutions of Γ_ϵ for $\epsilon \to 0$ provided that the limit exists. In the following we will first analyse the ϵ–uniformly perturbed games Γ_ϵ of Γ and determine their solutions. Knowing the solution of Γ_ϵ the limit solution for Γ will then be obvious. Since pooling equilibria do not exist for $c > \frac{w}{1-w}$, we will distinguish the cases $c > \frac{w}{1-w}$ and $c < \frac{w}{1-w}$. The highly special case $c = \frac{w}{1-w}$ is of no political relevance and will therefore be neglected. For given a priori–beliefs about G as described by w NATO is not interested in disarmament if $c > \frac{w}{1-w}$ whereas it would be willing to engage in disarmament if $c < \frac{w}{1-w}$.

a) The case $c > \frac{w}{1-w}$

This is the case where, according to its initial beliefs, NATO does not want to disarm. Consider now an ϵ–uniformly perturbed game Γ_ϵ of Gorby's NATO–game Γ with positive ϵ. Assume that d is chosen with minimum probability ϵ by both types G_i and G_p of player G. The expected payoff of N for $l(d) > 0$, given his observation of d, is then

$$\frac{w\epsilon\, l(d) - (1-w)\epsilon c l(d)}{w\epsilon + (1-w)\epsilon} = (w-(1-w)c)l(d)$$

which is negative for $c > \frac{w}{1-w}$. Thus, in case of $c > \frac{w}{1-w}$, player N will react to any such proposal d with $l(d) = 0$ where this, of course, is meant to mean that $l(d) = 0$ is chosen with maximal probability. If G_p (G_i) chooses d with (more than) minimum probability, clearly N also does not engage into a disarmament agreement. This proves

Proposition 3: If $c > \frac{w}{1-w}$, then in every ϵ–uniformly perturbed game Γ_ϵ of Gorby's NATO–game Γ player N will respond by $l(d) = 0$ if G_p chooses d with minimum probability ϵ. □

If ϵ is small, G_i will choose d with $d \geq c_i^{-1}$ with minimal probability, in equilibrium. If G_p uses such a proposal d with more than minimal probability, it will therefore be accepted. Thus, in equilibrium, G_p will choose d with $d < c_i^{-1}$ with minimal probability.

Assume now that $l(d) = 0$ is chosen with maximal probability for all $d < c_i^{-1}$, i.e. all agreements $l(d) = \hat{d}$ with $0 < \hat{d} \leq d$ are realized with the same minimum probability ϵ. Type G_i's payoff expectation for $d < c_i^{-1}$ is therefore $\epsilon \sum_{0<l\leq d} (1-c_i l)$. In such a situation it is clearly optimal for G_i to make the largest disarmament proposal

$$\bar{d}_i = \max\{mg : mg < c_i^{-1},\ m \in \mathbb{N}\}$$

which does not exceed his critical level c_i^{-1} beyond which he is not interested in disarmament agreements. The reason for this is that in an ϵ–uniformly perturbed game type G_i will want to allow player N to make as many mistakes as possible if $d < c_i^{-1}$.

Proposition 4: If ϵ (> 0) is small an equilibrium of an ϵ–uniformly perturbed game Γ_ϵ of Gorby's NATO–game Γ requires that type G_i will choose $\bar{d}_i$ with maximal probability and that player N responds to all $d < c_i^{-1}$ by choosing $l(d) = 0$ with maximal probability. □

According to Propositions 3 and 4 all type separating equilibria in ϵ–uniformly perturbed games Γ_ϵ have to be of the form

$$s = (\bar{d}_i, d_p, l(\cdot)) \text{ with } d_p \geq c_i^{-1},\ l(d) = \begin{cases} d & \text{if } d = d_p \\ 0 & \text{otherwise} \end{cases}$$

where this, of course, only means that the respective moves are chosen with maximal probability. We say that an equilibrium point of Γ is *uniformly perfect* if there exists a sequence $\{\Gamma_\epsilon^k\}_{k\in\mathbb{N}}$ of ϵ–uniformly perturbed games Γ_ϵ^k of Γ with $\Gamma_\epsilon^k \to \Gamma$ for $k \to \infty$ and with the property that one can find equilibria of the games Γ_ϵ^k which converge to s for $k \to \infty$.

Proposition 5: For $c > \frac{w}{1-w}$ only the type separating equilibria

$$s = (\bar{d}_i, d_p, l(\cdot))$$

$$\text{with } d_p \geq c_i^{-1} \text{ and } l(d) = \begin{cases} d & \text{if } d = d_p \\ 0 & \text{otherwise} \end{cases}$$

of Γ are uniformly perfect.

Proof: Assume an ϵ–uniformly perturbed game Γ_ϵ of Γ. From Proposition 4 it follows that G_i should use $d_i = \bar{d}_i$ with maximal probability if N behaves according to $l(\cdot)$, described in the Proposition above, with maximal probability. Given $c > \frac{w}{1-w}$ and that all $d \neq d_p$ are chosen with ϵ–probability by G_p player N should, according to Proposition 3, behave according to $l(\cdot)$ with maximal probability. If $d = d_p$ is the only voluntarily by N accepted disarmament proposal, type G_p will clearly want to make this proposal with maximal probability for ϵ sufficiently small. Thus in every ϵ–uniformly perturbed game Γ_ϵ with ϵ sufficiently small it is an equilibrium point to choose the moves described by the strategy vector s of Proposition 5 with maximal probability. Such a behavior obviously converges to s for $\epsilon \to 0$. □

Comparing Proposition 5 with Proposition 2 shows that Gorby's NATO–game Γ has considerably more type separating equilibria than uniformly perfect type separating equilibria. Especially the arbitrary choice of d_i in the range $d_i < c_i^{-1}$ has been eliminated by requiring uniform perfectness. Uniform perfectness causes type G_i to make always the largest disarmament proposal which is still acceptable to him.

In order to determine a unique solution for the games Γ with $c > \frac{w}{1-w}$, we have to select uniquely one type separating equilibrium point as the solution for every ϵ–uniformly perturbed game Γ_ϵ of Γ. Let

$$s = (\bar{d}_i, d_p, l(\cdot)) \text{ with } d_p \geq c_i^{-1}, l(d) = \begin{cases} d \text{ if } d = d_p \\ 0 \text{ otherwise} \end{cases}$$

and

$$\hat{s} = (\bar{d}_i, \hat{d}_p, \hat{l}(\cdot)) \text{ with } \hat{d}_p \geq c_i^{-1}, \hat{l}(d) = \begin{cases} d \text{ if } d = \hat{d}_p \\ 0 \text{ otherwise} \end{cases}$$

be two different type separating equilibria of Γ_ϵ where this, of course, means that the respective moves are chosen with maximal probability. In the restricted game for the comparison of s and $\hat{s}$ the only active players are those who choose different strategies in s and $\hat{s}$. Thus type G_i is no active player in the restricted game for the comparison of s and $\hat{s}$ and will therefore not matter when deciding whether s or $\hat{s}$ will be selected if s and $\hat{s}$ would be the only solution candidates. Now it is clear that G_p as well as player N both prefer s to $\hat{s}$ whenever $d_p > \hat{d}_p$ since both payoffs increase linearly in the disarmament level l of an agreement between G_p and N. In the terminology of equilibrium selection theory (HARSANYI and SELTEN, 1988) this can be expressed by saying that the equilibrium point s with the larger disarmament level d_p payoff dominates the equilibrium point $\hat{s}$ in the restricted game for the comparison of s and $\hat{s}$. As a consequence we can conclude

Proposition 6: For $c > \frac{w}{1-w}$ the solution of Gorby's NATO–game Γ is the type separating uniformly perfect equilibrium point $\bar{s} = (\bar{d}_i, D, l(\cdot))$ with

$$l(d) = \begin{cases} d \text{ for } d = D \\ 0 \text{ otherwise.} \end{cases}$$

Proof: For ϵ sufficiently small the equilibrium point of Γ_ϵ according to which all players choose the moves, prescribed by $\bar{s}$, with maximal probability will payoff dominate all other uniformly perfect equilibria. Relying on $\bar{s}$ with maximal probability is therefore the solution of Γ_ϵ. □

b) The case $c < \frac{w}{1-w}$

This is the case where, according to its initial beliefs, NATO is willing to accept disarmament proposals. Consider an ϵ–uniformly perturbed game Γ_ϵ of Gorby's NATO–game Γ with $c < \frac{w}{1-w}$. If $d > 0$ is chosen by G_p with at least the same positive probability as by G_i, player N's payoff expectation is at least

$$(w-(1-w)c)l(d)$$

which for $l(d) > 0$ is positive because of $c < \frac{w}{1-w}$. Since G_i will use all d_i with $d_i \geq c_i^{-1}$ with minimum probability ϵ, this implies that

$$l(d) = d \text{ for all } c_i^{-1} \leq d \leq D.$$

But given this behavior of player N in all ϵ–uniformly perturbed games Γ_ϵ, it follows that G_p will choose $d_p = D$ with maximal probability.

Proposition 7: For $c < \frac{w}{1-w}$ and every ϵ–uniformly perturbed game Γ_ϵ of Γ it is necessary that for $c_i^{-1} \leq d \leq D$ player N chooses $l\,(d) = d$ with maximal probability and that type G_p uses $d_p = D$ with maximal probability. □

According to Proposition 7 there is no analogue of the pooling equilibria described in Proposition 1. In an ϵ–uniformly perturbed game player N will always accept disarmament proposals d with $d \geq c_i^{-1}$ since he knows that G_i will not voluntarily make such proposals. Thus he is sure that meeting G_i is not more likely than meeting G_p and that $l(d) = d$ maximizes his payoff expectation given his observation $d \geq c_i^{-1}$.

Proposition 7 describes the essential political results for the case $c < \frac{w}{1-w}$, namely that any uniformly perfect equilibrium of Γ will require $l(d) = d$ for all $d \geq c_i^{-1}$ and $d_p = D$ together with $d_i < c_i^{-1}$, i.e. player N can deduce from the observation d whether he faces type G_i or type G_p of player G. What we do not know yet is how player N will react to proposals $d < c_i^{-1}$ and which proposals d_i type G_i will choose in the range $d_i < c_i^{-1}$.

Observe first of all that G_i cannot choose d_i with $0 < d_i < c_i^{-1}$ with minimum probability ϵ in an ϵ–uniformly perturbed game Γ_ϵ of Γ when ϵ becomes small. This would imply that both types use this proposal with the same probability and that player N must accept it with maximal probability. In the limit $\epsilon \to 0$ such a behavior would imply a positive contract probability for N and G_i in spite of $d_p = D$ which clearly would not be optimal in Γ_ϵ with ϵ sufficiently small nor in the game Γ itself.

Thus we know that all $0 < d_i < c_i^{-1}$ must be chosen with probability greater than ϵ by type G_i of player G. But in order to use all $0 < d_i < c_i^{-1}$ with more than minimum probability ϵ all these disarmament proposals d_i must yield the same payoff expectation for type G_i. Let $q_N^\epsilon(\cdot\,|d)$ denote the mixed local stratetgy of player N describing his behavior after having observed the disarmament proposal d. The condition that all disarmament proposals d_i with $0 < d_i < c_i^{-1}$ yield the same payoff expectation for G_i can be described as follows:

$$\sum_{0<l\leq d} q_N^{\epsilon}(l|d)(1-c_i l) = \sum_{0<l\leq \hat{d}} q_N^{\epsilon}(l|\hat{d})(1-c_i l)$$

for all $0 < d, \hat{d} < c_i^{-1}$. Since N has to avoid a disarmament contract with G_i, one, furthermore, must have

$$q_N^{\epsilon}(0|d) \longrightarrow 1 \text{ for } \epsilon \longrightarrow 0.$$

Now the condition $q_N^{\epsilon}(l|d) > \epsilon$ for $l > 0$ and $l = 0$ requires that

$$w\epsilon - (1-w)\, c\, q_i^{\epsilon}(d) = 0 \text{ for } 0 < d \leq c_i^{-1}$$

where $q_i^{\epsilon}(\cdot)$ denotes the mixed strategy of G_i in the ϵ–uniformly perturbed game Γ_{ϵ} of Γ, i.e. player G_i has to choose a mixed strategy which makes N indifferent between the choices $l > 0$ and $l = 0$. Thus we have

$$q_i^{\epsilon}(d) = \frac{w}{(1-w)c}\,\epsilon \text{ for all } 0 < d < c_i^{-1}$$

where the right hand–side is greater than ϵ due to $c < \frac{w}{1-w}$. Our results are summarized by

Proposition 8: For $c < \frac{w}{1-w}$ a uniformly perfect equilibrium point $s = (q_i, d_p, l(\cdot))$ of Γ requires that

(i) $q_i(d) = q_i(\hat{d}) > 0$ for all $0 < d, \hat{d} < c_i^{-1}$ and
$q_i(d) = 0$ for $d = 0$ and $d \geq c_i^{-1}$

(ii) $d_p = D$

(iii) $$l(d) = \begin{cases} d & \text{for } d \geq c_i^{-1} \\ 0 & \text{for } d < c_i^{-1}. \end{cases}$$

Proof: Since $d_i = 0$ and $d_i \geq c_i^{-1}$ exclude a positive payoff expectation of G_i, these disarmament proposals are realized with minimal probability in every ϵ–uniformly perturbed game Γ_ϵ of Γ. Thus $q_i(\cdot)$ must be the uniform discrete distribution on $0 < d < c_i^{-1}$ because $q_i^\epsilon(\cdot)$ is uniform, too. The results (ii) and (iii) are obvious implications of Proposition 7 and the equilibrium property of s. □

V. Non–signaling games

Up to now it has been assumed that the largest possible disarmament proposal D is not smaller than the critical level c_i^{-1} for disarmament proposals. Since only in the range $d \geq c_i^{-1}$ the imperialistic Gorby will not want to mimic the peaceful Gorby, the assumption $D \geq c_i^{-1}$ is absolutely necessary for signaling behavior to be in equilibrium.

Although one excludes type signaling behavior, it might be politically important to consider also the class of games Γ where

$0 < D \leq c_i^{-1}$.

In these games signaling equilibria are excluded since it always pays for G_i to mimic the behavior of G_p and to hide thereby its imperialistic intentions. Every pure equilibrium point $s = (d_i, d_p, l(\cdot))$ implies therefore $d_i = d_p$ if the NATO–player N is willing to accept any disarmament proposal in equilibrium, i.e. if $c < \frac{w}{1-w}$. Whereas for $c > \frac{w}{1-w}$ no disarmament agreement is achieved in equilibrium, the case $c < \frac{w}{1-w}$ provides a multiplicity of pooling equilibria with

$$0 < d_i = d_p = \bar{d} \leq D$$

and

$$l(d) = \begin{cases} d & \text{for } d = \bar{d} \\ 0 & \text{otherwise.} \end{cases}$$

To determine the uniformly perfect equilibrium behavior one has to explore again the ϵ–uniformly perturbed games Γ_ϵ of Γ with $0 < D < c_i^{-1}$. In case of $c > \frac{w}{1-w}$ both types of G will use $d = D$ with maximal probability in order to allow player N the most possible mistakes. Player N, in turn, will react to all disarmament proposals d by choosing $l(d) = 0$ with maximal probability.

Proposition 9: In case of $c > \frac{w}{1-w}$ and $0 < D < c_i^{-1}$ the only uniformly perfect equilibrium point $s = (d_i, d_p, l(\cdot))$ of Gorby's NATO–game Γ is given by

$$d_i = d_p = D$$

and

$$l(d) = 0 \text{ for all } 0 < d \leq D. \quad \square$$

For the remaining case $c < \frac{w}{1-w}$ together with $0 < D < c_i^{-1}$ the situation is more complicated. To make N indifferent between all moves $0 \leq l \leq d$ for $d \neq \bar{d}$ it is required that

$$\frac{q_i^\epsilon(d)}{q_p^\epsilon(d)} = \frac{w}{(1-w)c} > 1$$

which implies

$$q_i^\epsilon(d) > \epsilon.$$

Thus $q_N^\epsilon(\cdot\,|\,d)$ must be such that

$$\sum_{0<l\leq d} q_N^\epsilon(l\,|\,d)(1-c_i l) = \sum_{0<l\leq \bar{d}} q_N^\epsilon(l\,|\,\bar{d})(1-c_i l)$$

for all $d > 0$ and $d \neq \bar{d}$ where $q_N^\epsilon(l\,|\,\bar{d}) = \epsilon$ for all $0 \leq l < \bar{d}$ since G_p chooses $\bar{d}$ with at least the same probability as G_i.

Thus the equilibrium behavior $q^\epsilon = (q_i^\epsilon(\,),q_p^\epsilon(\,),q_N^\epsilon(\cdot\,|\,\cdot))$ in Γ_ϵ for the case $c < \frac{w}{1-w}$ and $0 < D < c_i^{-1}$ can be described as follows: Type G_i of G will choose voluntarily all non–intended disarmament proposals d ($\neq \bar{d}$) with $0 < d$ as to make the NATO–player N, after observing d, indifferent between all his moves l(d) with $0 \leq l(d) \leq d$. The NATO–player N, in turn, has to choose an appropriate local strategy $q_N^\epsilon(\cdot|d)$ as to make the voluntary choice of d by type G_i of the Soviet Union player G equally profitable as the choice of $\bar{d}$. In the limit $\epsilon \to 0$ both probabilities $q_i^\epsilon(d)$ and $q_p^\epsilon(d)$ for $d > 0$ and $d \neq \bar{d}$ converge to 0 since $q_p^\epsilon(d) = \epsilon$ and $q_i^\epsilon(d) = \frac{w}{(1-w)c}\,\epsilon$ for all $d > 0$, $d \neq \bar{d}$. For the limit $q_N(\cdot|d)$ for $d > 0$ and $d \neq \bar{d}$ of the local strategies $q_N^\epsilon(\cdot|d)$ one must have

$$\sum_{0<l\leq d} q_N(l|d)(1-c_i l) = 1-c_i\bar{d} \quad \text{for all } d > 0,\ d \neq \bar{d},$$

and

$$q_N(l|\bar{d}) = \begin{cases} 1 & \text{for } l = \bar{d} \\ 0 & \text{otherwise.} \end{cases}$$

The specification of $q_N(\ |d)$ for $d > 0$, $d \neq \bar{d}$, has, of course, to satisfy that

$$\sum_{0<l\leq d} q_N(l|d)(1-c_p l) \leq 1-c_p\bar{d},$$

i.e. type G_p should not be seduced to make other proposals than $\bar{d}$. It is easy to see that this condition can be implied by the upper condition if the probabilities $q_N(l|d)$ for $l < \bar{d}$ are sufficiently high.

This indicates that $q_N(\cdot|d)$ for $d > 0$, $d \neq \bar{d}$, has to put most of the weight on disarmament levels l with $l < \bar{d}$. On the one hand such proposals are more profitable for G_i who has to be compensated for the lower probability of achieving a contract when choosing $d \neq \bar{d}$; on the other hand agreements $l < \bar{d}$ are less profitable for G_p so that G_p is not seduced to deviate from his equilibrium proposal $d_p = \bar{d}$.

Proposition 10: In case of $c < \frac{w}{1-w}$ and $0 < D < c_i^{-1}$ all uniformly perfect equilibrium points $q = (d_i, d_p, q_N(\cdot|\cdot))$ are of the following form:

$$d_i = d_p = \bar{d} \text{ with } 0 < \bar{d} \leq D$$

$$q_N(l|\bar{d}) = \begin{cases} 1 & \text{for } l = \bar{d} \\ 0 & \text{otherwise} \end{cases}$$

and for all $d > 0$, $d \neq \bar{d}$:

$$\sum_{0<l\leq d} q_N(l|d)(1-c_i l) = 1-c_i d$$

$$\sum_{0<l\leq d} q_N(l|d)(1-c_p l) \leq 1-c_p \bar{d}. \quad \square$$

As illustrated above the mixed local strategies are typically of the form that most of the weight has to be on accepting proposals $l < \bar{d}$ in order to make G_i indifferent between $d_i = d$ and $d_i = \bar{d}$ for $d > 0$, $d \neq \bar{d}$, and in order to preserve G_p's incentive for choosing $d_p = \bar{d}$ with maximal probability.

VI. Political implications

In the game with complete information also NATO is informed about Gorby's true type i.e., when deciding how to react to a proposal d (> 0), NATO would know whether this proposal is made by G_i or G_p. As a consequence the two strategic situations starting with G_i' s or G_p' s proposal are subgames i.e., informationally closed strategic substructures of the overall game situation.

In the game with complete information NATO will definitely react to all proposals $d > 0$ of G_p by $l(d) = d$ whereas proposals $d > 0$ by G_i will be rejected i.e., by choosing $l(d) = 0$. Thus every subgame perfect equilibrium (SELTEN, 1975) will require G_i to make the largest possible proposal D and NATO to accept this proposal D of G_p and to refuse any proposal $d > 0$ by the imperialistic Gorby–type G_i. Since all proposals $d > 0$ of G_i are rejected, subgame perfectness alone does not uniquely specify the choice of G_i. But as for the case $c > \frac{w}{1-w}$ uniform perfectness will require G_i to choose the largest proposal $\bar{d}_i$ in the range $d < c_i^{-1}$.

Thus in case of complete information the political implications are straightforward. If there is any essential disarmament agreement then it must be common knowledge that the Soviet Union is mainly interested in effective defense and has no offensive military intentions. Furthermore disarmament will go as far as truly peaceful political leaders can justify.

In the game with incomplete information NATO's problem is that a different treatment of G_i and G_p cannot be directly enforced but only via the different incentives of G_i and G_p. It has been shown above that NATO's initial beliefs determine the essential case distinction $c > \frac{w}{1-w}$ and $c < \frac{w}{1-w}$. In case of $c > \frac{w}{1-w}$ NATO is not willing to engage in disarmament given its a priori–beliefs as expressed by the probability parameter w. For $c < \frac{w}{1-w}$ disarmament is acceptable for NATO according to its initial beliefs even though it cannot exclude to encounter the imperialistic type of the Soviet Union.

Proposition 6 and 8 describe the solution of Gorby's NATO–game Γ for both cases, $c > \frac{w}{1-w}$ as well as $c < \frac{w}{1-w}$. Irrespective whether the parameter c is smaller or greater than the critical level $\frac{w}{1-w}$ the peaceful type G_p of the Soviet Union G is always able to signal its peaceful intentions by proposing the maximal possible disarmament level $d = D$. For the other players the solution behavior differs for $c > \frac{w}{1-w}$ and $c < \frac{w}{1-w}$. Whereas for $c > \frac{w}{1-w}$ the imperialistic type G_i of the Soviet Union G chooses the maximal disarmament proposal d_i with $d_i < c_i^{-1}$ and the NATO–player N refuses all proposals $d < D$, type G_i of G realizes all proposals $0 < d_i < c_i^{-1}$ with the same positive probability and N refuses only those proposals d with $0 < d < c_i^{-1}$ whenever $c < \frac{w}{1-w}$.

To derive these results one has to apply, furthermore, different solution ideas. Whereas for $c < \frac{w}{1-w}$ there exists a unique uniformly perfect equilibrium point, one has generally many uniformly perfect type separating equilibria in case of $c > \frac{w}{1-w}$ as shown by Proposition 5. To derive unambiguous political results for the latter case we essentially have added the requirement that, if all players, using different strategies in two uniformly perfect equilibria, prefer one over the other, the more preferred equilibrium point will be chosen. Thus our solution of the case $c > \frac{w}{1-w}$ relies on some trust in social rationality which underlies the notion of payoff dominance.

More generally, the political results depend crucially on whether D is smaller or greater than c_i^{-1} as illustrated by the following table:

c_i \ c	$c > \frac{w}{1-w}$	$c < \frac{w}{1-w}$
$D \geq c_i^{-1}$	many uniformly perfect signaling equilibria; solution: $d_p = D$–signaling	only $d_p = D$–signaling is uniformly perfect
$D < c_i^{-1}$	only $d_i = d_p = D$ and $l(d) = 0$ for all d is uniformly perfect	all pooling equilibria $d_i = d_p = \bar{d} > 0$ and $q_N(d\mid d) = \begin{cases} 1 & \text{for } d = \bar{d} \\ <1 & \text{for } d \neq \bar{d} \end{cases}$ are uniformly perfect

Table 1: The influence of disarmament cost parameters c (NATO) and c_i (imperialistic type of Soviet Union) on political results.

To derive a unique solution for $c < \frac{w}{1-w}$ and $0 < D < c_i^{-1}$ one again has to explore the ϵ–uniformly perturbed games Γ_ϵ of Gorby's NATO–game Γ with $D < c_i^{-1}$. Obviously, payoff dominance will not suffice to select a solution since G_i is interested in a small disarmament level $\bar{d}$, whereas G_p prefers a larger one. One would have to employ further selection criteria in order to derive unambiguous political results for the games Γ with $D < c_i^{-1}$. Here we do not engage into a more detailed discussion of the case $D < c_i^{-1}$ since the main political results for this case are already given by Table 1 and since such a discussion would require new techniques (see HARSANYI and SELTEN, 1988, and GÜTH and KALKOFEN, 1989, as well as GÜTH and VAN DAMME, 1989, for an application).

Another reason not to engage into a more thorough investigation of the case $D < c_i^{-1}$ is that we presently observe disarmament proposals by player G which seem to resemble the $d_p = D$–signaling policy, i.e. we apparently face the peaceful type G_p of G who reveals his type by making – up to now – unimaginable disarmament proposals. To conclude from this that the present state of the world resembles the case $D \geq c_i^{-1}$ requires, of course, a comparison of these disarmament proposals and the cost level c_i^{-1} of the imperialistic type G_i of the Soviet Union player G. It is here where a quantitative version of the defense efficiency hypothesis would be needed. Such a quantitative form of the defense efficiency hypothesis could be expressed by defining the critical disarmament level $d = c_i^{-1}$ which makes G_i indifferent between the status quo on the one hand and the political superiority after a successful disarmament campaign on the other hand, i.e. we are asking: How much disarmament d will offset G_i's political superiority due to a successful disarmament proposal?

The defense efficiency hypothesis states mainly that $c_p \leq 0 < c_i$, i.e. only the imperialistic type suffers from disarmament. A peaceful type would not mind to decrease those military forces which are mainly designed for offensive military operations and to substitute them by more defense oriented weapon systems if necessary. As our analysis has shown the parameter c_p has no strategic influence at all in the range $c_p \leq 0$. Thus all what matters is that a peaceful Gorby gains from disarmament; the size of his gains does not influence the solution behavior. Compared to this the cost parameter c of the NATO–player N is decisive for whether uniformly perfect pooling equilibria can exist at all. All what is needed to know is whether the parameter c is greater or smaller than the relative probability $\frac{w}{1-w}$ of the peaceful type G_p of the Soviet Union player G. The political question by which one can rephrase this condition is: Given its a priori–beliefs concerning the true military intentions of the Soviet Union, is NATO nevertheless strongly interested in essential reductions of offensive weapon systems? If this question is answered in the affirmative, this indicates that the presently prevailing state of the world resembles the case $c < \frac{w}{1-w}$. For $c > \frac{w}{1-w}$ the risk, involved in engaging into disarmament although G can be of the imperialistic type, is obviously considered as more prohibitive for disarmament policy.

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